

The opinion in support of the decision being entered today was *not* written for publication and is *not* binding precedent of the Board.

UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE BOARD OF PATENT APPEALS  
AND INTERFERENCES

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*Ex parte* STEPHEN A. STOCKMAN,  
SERGE L. RUDAZ, and  
MIRA S. MISRA

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Appeal 2006-2769  
Application 09/846,980  
Technology Center 1700

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Decided: April 5, 2007

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Before CHUNG K. PAK, THOMAS A. WALTZ, and  
CATHERINE Q. TIMM, *Administrative Patent Judges*.

PAK, *Administrative Patent Judge*.

DECISION ON APPEAL

This is an appeal from the Examiner's final rejection of claims 1 and 3 through 60, all of the claims pending in the above-identified application. We have jurisdiction pursuant to 35 U.S.C. §§ 6 and 134.

## I. APPEALED SUBJECT MATTER

The subject matter on appeal is directed to a method of producing p-type III-V nitride layers in a light emitting diode (Specification 1 and 4). Further details of the appealed subject matter are recited in representative claims 1 and 31,<sup>1</sup> which are reproduced below:

1. A method for manufacturing a p-type III-V nitride compound semiconductor comprising:

growing in a chamber a III-V nitride compound semiconductor layer at a first temperature while introducing acceptor impurities into said layer to form an acceptor-doped layer, said chamber containing one or more gases providing hydrogen such that said hydrogen passivates at least some of said acceptor impurities;

cooling said acceptor-doped layer to a second temperature significantly lower than said first temperature during a cool-down process;

preventing additional hydrogen from diffusing into said acceptor-doped layer substantially during the cool-down process;

causing said acceptor-doped layer to be a p-type layer, having p-type conductivity and a hold density between approximately  $3 \times 10^{15} \text{ cm}^{-3}$  and  $1 \times 10^{18} \text{ cm}^{-3}$ , after said cool-down process; and

after said cooling, heating said p-type layer to a third temperature greater than the second temperature and less than 625°C to remove hydrogen from said p-type later thereby increasing said hole density and lowering the resistivity of said p-type layer.

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<sup>1</sup> The Appellants only argue the limitations recited in claims 1 and 31 in the Brief and the Reply Brief (Br. 4-7 and Reply Br. 1-4).

31. A method for manufacturing a p-type III-V nitride compound semiconductor comprising:

growing in a chamber III-V nitride compound semiconductor layer at a first temperature while introducing acceptor impurities into said layer to form an acceptor-doped layer, said chamber containing one or more gases providing hydrogen such that said hydrogen passivates at least some of said acceptor impurities;

cooling said acceptor-doped layer to a second temperature significantly lower than said first temperature during a cool-down process, thereby causing said acceptor-doped layer to be a p-type layer, having p-type conductivity and a hole density between approximately  $3 \times 10^{15} \text{ cm}^{-3}$  and  $1 \times 10^{18} \text{ cm}^{-3}$ , after said cool-down process; and

after said cooling, heating said p-type layer to a third temperature greater than the second temperature and less than 625°C to remove hydrogen from said p-type layer thereby increasing said hole density and lowering the resistivity of said p-type layer.

## II. PRIOR ART

As evidence of unpatentability of the claimed subject matter, the Examiner relies upon the following references:

Nitta	US 5,789,265	Aug. 4, 1998
Koike	US 5,811,319	Sep. 22, 1998
Peng	US 5,895,223	Apr. 20, 1999
Bour	US 5,926,726	Jul. 20, 1999
Furukawa	US 6,017,807	Jan. 25, 2000
Takatani	US 6,100,174	Aug. 8, 2000

### III. REJECTION

The Examiner has rejected the claims on appeal as follows:

- 1) Claims 1, 3 through 5, 12 through 30, 31 through 35, and 42 through 60 under 35 U.S.C. § 103(a) as unpatentable over the combined disclosures of Bour, Koike and Furukawa;;
- 2) Claims 6, 9, 11, 36, 39, 40, and 41 under 35 U.S.C. § 103(a) as unpatentable over the combined disclosures of Bour, Koike, Furukawa, and Takatani;
- 3) Claims 10 and 50 under 35 U.S.C. § 103(a) as unpatentable over the combined disclosures of Bour, Koike, Furukawa, Takatani, and Peng;
- 4) Claims 13 and 43 under 35 U.S.C. § 103(a) as unpatentable over the combined disclosures of Bour, Koike, Furukawa, and Peng; and
- 5) Claims 7, 8, 37, and 38 under 35 U.S.C. § 103(a) as unpatentable over the combined disclosures of Bour, Koike, Furukawa, and Nitta.

### IV. ISSUE

1. Would one of ordinary skill in the art have been led to anneal, after cooling, a grown p-type III-V nitride layer at a temperature higher than a cooling temperature, but less than 625°C within the meaning of 35 U.S.C. § 103?<sup>2</sup>

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<sup>2</sup> This issue is dispositive to all of the rejections set forth in the Answer. As is apparent from the Brief and the Reply Brief, the Appellants' arguments raise only this issue.

## V. PRINCIPLES OF LAW

Under 35 U.S.C. §103, the obviousness of an invention cannot be established by combining the teachings of the prior art references absent some teaching, suggestion or incentive supporting the combination.

*ACS Hosp. Sys., Inc. v. Montefiore Hosp.*, 732 F.2d 1572, 1577, 221 USPQ 929, 933 (Fed. Cir. 1984). This does not mean that the cited prior art references must specifically suggest making the combination. *B.F. Goodrich Co. v. Aircraft Braking Sys. Corp.*, 72 F.3d 1577, 1582, 37 USPQ2d 1314, 1318 (Fed. Cir. 1996); *In re Nilssen*, 851 F.2d 1401, 1403, 7 USPQ2d 1500, 1502 (Fed. Cir. 1988). Rather, the test for obviousness is what the combined teachings of the prior art references would have suggested to those of ordinary skill in the art. *In re Young*, 927 F.2d 588, 591, 18 USPQ2d 1089, 1091 (Fed. Cir. 1991); *In re Keller*, 642 F.2d 413, 425, 208 USPQ 871, 881 (CCPA 1981). In evaluating the prior art references for a suggestion, it is proper to take into account not only the specific teachings of the references, but also any inferences which one skilled in the art would reasonably be expected to draw therefrom.

*In re Preda*, 401 F.2d 825, 826, 159 USPQ 342, 344 (CCPA 1968).

A prima facie case of obviousness exists when the claimed range and the prior art range do not overlap but are close enough such that one skilled in the art would have expected them to produce products having the same properties. *Titanium Metals Corp. of Am. v. Banner*, 778 F.2d 775, 783, 227 USPQ 773, 779 (Fed. Cir. 1985). Moreover, “discovery of an optimum value of a result effective variable in a known process is ordinarily within

the skill of the art.” *In re Boesch*, 617 F.2d 272, 276, 205 USPQ 215, 219 (CCPA 1980).

## VI. RELEVANT FACTUAL FINDINGS

1. The Appellants do not challenge the Examiner’s findings at pages 4 and 5 of the Answer that:

Bour et al. teaches a carrier gas of H<sub>2</sub> is introduced with reaction gases NH<sub>3</sub> and TMGa and impurity gas Cp<sub>2</sub>Mg to a reactor to form a p-type GaN layer at a temperature of 900°C (col 6, [sic, ll.] 20-26) After formation of the p-type nitride layer the reactant gases are switched out of the reactor and a gas which prevents the decomposition of the III-V layer at such high growth temperatures, NH<sub>3</sub> is added (col 5, In [sic, ll.] 60-65 and col 6, In [sic, ll.] 31-35). Bour et al also teaches a reactor is cooled down to a temperature where surface decomposition of as-grown p-type GaN layer will not further occur, where upon attainment of the this temperature, the preventer gas, NH<sub>3</sub>, is switched out of the reactor and the remaining cool down occurs in molecular N and acceptor activation is preformed [sic, performed] either as the reactor is further cooled or maintained at a temperature of 600°C for 20-40 minutes and during the cool down of the reactor a flow of molecular N, N<sub>2</sub>, is maintained in the reactor. (col 6, In [sic, ll.] 40-65).

2. The Appellants do not challenge the Examiner’s determinations at page 6 of the Answer that:

In a method of growing p-type gallium nitride, Koike et al. teaches three p-layers of Mg-doped Al<sub>x</sub>Ga<sub>1-x</sub>N forms a p-layer (61) which acts as a clad layer having a hole concentrations of 5 x 10<sup>17</sup>/cm<sup>3</sup>, 5 x 10<sup>17</sup>/cm<sup>3</sup> and 2 x 10<sup>17</sup>/cm<sup>3</sup> and an Mg concentrations of 1 x 10<sup>20</sup>/cm<sup>3</sup>, 1 x 10<sup>20</sup>/cm<sup>3</sup> and 2 x 10<sup>20</sup>/cm<sup>3</sup>, respectively (col 3, [sic, ll.] 50-65). Koike also teaches electron rays were uniformly irradiated into the p-layer

using a reflective electron beam, where this irradiation changed the p-layer into a p-type conductive semiconductor with a hole concentration of  $5 \times 10^{17}/\text{cm}^3$ ,  $5 \times 10^{17}/\text{cm}^3$  and  $2 \times 10^{17}/\text{cm}^3$  and a resistivity of 0.5 ohm-cm, 0.8 ohm-cm and 1.5 ohm-cm, respectively (col 5, In [sic, ll.] 14-26). Koike et al also teaches forming metal electrode, such as nickel or aluminum, are formed on semiconductor devices utilizing GaN group compounds such as AlGaN after the semiconductor surface is cleaned by wet chemical etching, utilizing a wet chemical etchant such as buffered hydrogen fluoride (col 1, In [sic, ll.] 15-30).

It would have been obvious to a person of ordinary skill in the art at the time of the invention to modify Bour with Koike's electron beam irradiation because it would have produced p-type conductive semiconductors with low resistivities.

3. The Appellants only argue that the prior art references would not have suggested "heating said p-type layer to a third temperature greater than the second temperature and less than 625°C to remove hydrogen from said p-type layer..." recited in claims 1 and 31.

4. Bour teaches (col. 6, ll. 46-58) that:

Upon attainment of this temperature [around 600° C. to 800° C.], the N outdiffusion preventor gas, NH<sub>3</sub>, is switched out of reactor 10, as shown in step 35 in **FIG. 6**, and acceptor activation is performed either as the reactor is further cooled down or at a temperature maintained for a given period of time as indicated at step 36. As an example, if the temperature is maintained at 600° C., then the time period for activation may be tens of minutes, such as, for example, between about 20 to about 40 minutes. This anneal process indicated in **FIG. 3** wherein, during the cooldown of reactor 10, a flow of molecular N, N<sub>2</sub>, is maintained in the reactor as acceptor activation is carried out in the matter as just described.

It can be inferred from this passage that the type of annealing (removing hydrogen from a p-type layer) employed, e.g., at a temperature of 600°C or below (the temperature reached during “further cooldown”) is dependent on desired time periods for activation of the p-type layer. This passage would have provided one of ordinary skill in the art with a reasonable expectation of successfully annealing Bour’s p-type layer using any and all of the above temperatures in the presence of nitrogen at given activation time periods.

5. The claimed process involving heating a p-type layer to 600°C. from a cool-down temperature just below 600°C. (e.g., 599.999999°C.) is essentially identical to Bour’s activation step involving cooling down the p-type layer to and maintaining it at about 600°C. The claimed and prior art temperature ranges are so close that one skilled in the art would have expected them to produce products having the same or similar properties.

6. The Appellants acknowledge at page 3 of the Specification that one of ordinary skill in the art recognizes that the annealing temperatures at or below 600°C exemplified in Bour are desirable. Specifically, the Specification states at page 3 that “as is recognized by those skilled in the art, temperatures greater than 600°C increasingly reduce the intensity of the LED light emission due to the degradation of the crystallinity of the GaN at such temperatures.”<sup>3</sup>

## VII. ANALYSIS AND CONCLUSIONS OF LAW

The Appellants do not challenge the Examiner’s findings at pages 4 and 5 of the Answer that:

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<sup>3</sup> Furukawa and the other prior art references cited are unnecessary for this analysis.

Bour et al. teaches a carrier gas of H<sub>2</sub> is introduced with reaction gases NH<sub>3</sub> and TMGa and impurity gas Cp<sub>2</sub>Mg to a reactor to form a p-type GaN layer at a temperature of 900°C (col 6, [ll.] 20-26) After formation of the p-type nitride layer the reactant gases are switched out of the reactor and a gas which prevents the decomposition of the III-V layer at such high growth temperatures, NH<sub>3</sub> is added (col 5, In [sic, ll.] 60-65 and col 6, In [sic, ll.] 31-35). Bour et al also teaches a reactor is cooled down to a temperature where surface decomposition of as-grown p-type GaN layer will not further occur, where upon attainment of this temperature, the preventer gas, NH<sub>3</sub>, is switched out of the reactor and the remaining cool down occurs in molecular N and acceptor activation is performed [sic, performed] either as the reactor is further cooled or maintained at a temperature of 600°C for 20-40 minutes and during the cool down of the reactor a flow of molecular N, N<sub>2</sub>, is maintained in the reactor. (col 6, In [sic, ll.] 40-65).

*See Br. 4-7 and Reply Br. 1-4.* Nor do the Appellants challenge the Examiner's determinations at page 6 of the Answer that:

In a method of growing p-type gallium nitride, Koike et al. teaches three p-layers of Mg-doped Al<sub>x</sub>Ga<sub>1-x</sub>N forms a p-layer (61) which acts as a clad layer having a hole concentrations of 5 x 10<sup>17</sup>/cm<sup>3</sup>, 5 x 10<sup>17</sup>/cm<sup>3</sup> and 2 x 10<sup>17</sup>/cm<sup>3</sup> and an Mg concentrations of 1 x 10<sup>20</sup>/cm<sup>3</sup>, 1 x 10<sup>20</sup>/cm<sup>3</sup> and 2 x 10<sup>20</sup>/cm<sup>3</sup>, respectively (col 3, [ll.] 50-65). Koike also teaches electron rays were uniformly irradiated into the p-layer using a reflective electron beam, where this irradiation changed the p-layer into a p-type conductive semiconductor with a hole concentration of 5 x 10<sup>17</sup>/cm<sup>3</sup>, 5 x 10<sup>17</sup>/cm<sup>3</sup> and 2 x 10<sup>17</sup>/cm<sup>3</sup> and a resistivity of 0.5 ohm-cm, 0.8 ohm-cm and 1.5 ohm-cm, respectively (col 5, In [sic, ll.] 14-26). Koike et al also teaches forming metal electrode, such as nickel or aluminum, are formed on semiconductor devices utilizing GaN group compounds such as AlGaN after the semiconductor surface is cleaned by wet chemical etching, utilizing a wet chemical

etchant such as buffered hydrogen fluoride (col. 1, In [sic, ll.] 15-30).

It would have been obvious to a person of ordinary skill in the art at the time of the invention to modify Bour with Koike's electron beam irradiation because it would have produced p-type conductive semiconductors with low resistivities.

*See* Br. 4-7 and Reply Br. 1-4. The Appellants only argue that the prior art references would not have suggested "heating said p-type layer to a third temperature greater than the second temperature and less than 625° C. to remove hydrogen from said p-type layer..." recited in claims 1 and 31. *See Id.* The dispositive question is, therefore, whether one of ordinary skill in the art would have been led to anneal, after cooling, a p-type III-V nitride layer at a temperature higher than a cooling temperature, but less than 625°C. within the meaning of 35 U.S.C. § 103. On this record, we answer this question in the affirmative.

As recognized by the Examiner (Answer 4-5), Bour teaches (col. 6, ll. 46-58):

Upon attainment of this temperature [around 600° C. to 800° C.], the N outdiffusion preventor gas, NH<sub>3</sub>, is switched out of reactor 10, as shown in step 35 in FIG. 6, and acceptor activation is performed either as the reactor is further cooled down or at a temperature maintained for a given period of time as indicated at step 36. As an example, if the temperature is maintained at 600° C., then the time period for activation may be tens of minutes, such as, for example, between about 20 to about 40 minutes. This anneal process indicated in FIG. 3 wherein, during the cooldown of reactor 10, a flow of molecular N, N<sub>2</sub>, is maintained in the reactor as acceptor activation is carried out in the matter as just described.

It can be inferred from this passage that the type of annealing (removing hydrogen from a p-type layer) employed, e.g., at a temperature of 600°C. or below (the temperature reached during “further cooldown”) is dependent on desired time periods for activation of the p-type layer. *In re Preda*, 401 F.2d 825, 826, 159 USPQ 342, 344 (CCPA 1968). This passage would have provided one of ordinary skill in the art with a reasonable expectation of successfully annealing Bour’s p-type layer using any and all of the above temperatures in the presence of nitrogen at given activation time periods. *Preda*, 401 F.2d at 826, 159 USPQ at 344. Therefore, using a combination of further cooling down and heating Bour’s p-type layer at workable activation temperatures (below 600°C. and/or at 600°C.) to obtain desired activation time is well within the ambit of one of ordinary skill in the art. *Boesch*, 617 F.2d at 276, 205 USPQ at 219 (“[D]iscovery of an optimum value of a result effective variable in a known process is ordinarily within the skill of the art.”). This is especially true in this situation since the claimed process involving heating the p-type layer to 600°C. from a cool-down temperature just below 600°C. (e.g., 599.9999°C.) is essentially identical to Bour’s activation step involving cooling the p-type layer to and then maintaining it at about 600°C. *Compare Titanium Metals Corp. of Am. v. Banner*, 778 F.2d at 783, 227 USPQ at 779(A prima facie case of obviousness exists when the claimed range and the prior art range do not overlap but are close enough such that one skilled in the art would have expected them to produce products having the same properties). As is apparent from the Appellants’ admission at page 3 of the Specification, one of ordinary skill in the art recognizes that the annealing temperatures at or

below 600°C exemplified in Bour are desirable since “as is recognized by those skilled in the art, temperatures greater than 600°C increasingly reduce the intensity of the LED light emission due to the degradation of the crystallinity of the GaN at such temperatures.”<sup>4</sup>

Accordingly, for the factual findings set forth above and in the Answer, we determine that the prior art relied upon by the Examiner would have rendered the subject matter recited in the claims on appeal obvious within the meaning of 35 U.S.C. § 103.

## VII. ORDER

The decision of the Examiner is affirmed.

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<sup>4</sup> Furukawa and the other prior art references cited are unnecessary for this analysis.

Appeal 2006-2769  
Application 09/846,980

VIII. TIME PERIOD

No time period for taking any subsequent action in connection with this appeal may be extended under 37 C.F.R. § 1.136(a)(1).

AFFIRMED

tf/ls

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